INTERNATIONAL JOURNAL OF PEST MANAGEMENT, 1997, **43**(3) 187–190

REP-1997-069
997-067

Reducing bird repellent application rates by the addition of sensory stimuli

(*Keywords: Agelaius phoeniceus*, bird repellents, methiocarb, Red-winged Blackbird, sensory stimuli)

CURTIS O. NELMS† and MICHAEL L. AVERY‡

US Department of Agriculture, Denver Wildlife Research Center, Florida Field Station, 2820 East University Avenue, Gainesville, Florida 32641 USA

Abstract. Red-winged Blackbirds (*Agelaius phoeniceus*) cause substantial damage to a variety of crops throughout North America. Nonlethal methods for controlling damage are generally ineffective, and environmental and cost concerns have limited the availability of chemical repellents such as methiocarb. One means of potentially lowering the effective application rate of methiocarb and similar aversive compounds is by combining the treatment with sensory cues. We tested groups ($n=4$) of male Red-winged Blackbirds in a series of 4-day feeding trials using brown rice treated with 0·025% (g/g) methiocarb, five times less than the previously established effective bird repellent rate. Each methiocarb treatment suppressed rice consumption, whether the repellent was alone or combined with a visual (red dye) and/or volatile (methylpyrazine) cue. When rice treated with just the sensory cues was subsequently presented, the red dye, but not the methylpyrazine, continued to deter feeding on rice. These results show that post-ingestive chemical repellents such as methiocarb can be effective at reduced rates provided the repellent is paired with an aversive visual cue. The addition of aversive stimuli may be particularly useful in reducing damage to seeded crops and in protecting birds from incidental ingestion of toxic granular pesticides.

1. Introduction

Concerns about possible harmful effects of residues have contributed to the reduced availability of bird repellent chemicals for crop protection (Tobin and Dolbeer, 1987; Dolbeer *et al.*, 1994). One approach to lowering the amount of chemical repellent used, and thereby reducing residues, is to treat only a portion of the crop (Avery, 1989). This tactic lowers the total amount of chemical applied but does not alter the repellent level on the individual treated items.

An alternative approach is to reduce the application rate. This decreases the total amount of chemical used and eliminates the risk of accidental ingestion of food treated at the full repellent level. The drawback of this approach is that repellents applied at reduced rates may give less protection.

One possibility for maintaining effectiveness at reduced application rates is to enhance the repellent with appropriate sensory stimuli (Bullard *et al.*, 1983a,b; Greig-Smith and Rowney, 1987; Mason, 1989). Bullard *et al.* (1983b) offered Red-winged Blackbirds (*Agelaius phoeniceus*) sunflower heads treated at various methiocarb levels with and without calcium carbonate applied as a cue. Examination of their results (Tables 2 and 4 in Bullard *et al.*, 1983b) revealed that the higher rates without the cue were more effective than lower methiocarb rates applied with the cue. Similarly, Elmahdi *et al.* (1985) found that Red-billed Quelea (*Quelea quelea*) consumed approximately twice as much wheat treated with 0·0015% (g/g) methiocarb plus calcium carbonate than they did wheat treated at 0·008% (g/g).

Previously, a 0·125% (g/g) methiocarb treatment effectively reduced consumption of brown rice by captive Red-winged Blackbirds (Avery and Nelms, 1990). The treatment rate of 0·125% was determined to be the minimum effective repellent rate for protection of seeded rice (Holler *et al.*, 1985), and this treatment was even more effective when it was paired with colour, taste, and/or odour stimuli (Avery and Nelms, 1990). Furthermore, the sensory cues alone continued to suppress rice consumption subsequent to removal of the methiocarb.

Because of concern by regulatory agencies of potential hazards associated with methiocarb use (e.g. Dolbeer *et al.*, 1994), it seemed reasonable to determine if the same cues that proved effective when paired with the 0·125% methiocarb treatment would also be effective when paired with a substantially lower level of methiocarb. If so, then perhaps repellent effectiveness could be retained and hazard reduced. The objectives of this study, therefore, were to: (1) determine repellency of 0·025% (g/g) methiocarb, alone and paired with visual, taste, and olfactory cues; (2) determine the effects on consumption of the cues alone, subsequent to pairing with 0·025% methiocarb; and (3) compare the repellency of 0·025% methiocarb-cue treatments with that of 0·125% methiocarb without cues.

2. Methods

Because Red-winged Blackbirds are gregarious and usually feed in flocks, social interactions might be important in their feeding behaviour. We chose not to eliminate that aspect from our study and tested birds in groups of four individuals.

Birds were captured locally and housed (20–25 birds per $1{\cdot}8 \times 1{\cdot}2 \times 1{\cdot}2$ m^3 cage) in an outdoor aviary 6–8 months prior to testing. For each trial, we selected birds randomly from among those that had been in captivity longest and acclimated them for 2–3 days to a $3{\cdot}2 \times 9{\cdot}7 \times 1{\cdot}8$ m^3 test enclosure.

Feeding trials were conducted on consecutive days. Maintenance food (brown rice, wheat, cracked yellow corn, and layer crumbles) was removed at 0730 h, and at 0830 h, birds were given one bowl (14 cm diameter, 8·5 cm deep) of test food (brown rice) and one bowl of alternative food (F-R-M Layer

†Present address: USFWS, Roosevelt FWMAO, Roosevelt, Utah, 84006, USA.
‡To whom correspondence should be addressed.

Crumbles, Flint River Mills, Bainbridge, Georgia, USA). On the first day, we randomly determined the positions of the test and alternative foods and maintained them for the remainder of the trial. A 1·3 m high partition separated the food bowls, which were placed at ground level.

Birds received only untreated food on days 1 and 4, but on days 2 and 3, the condition of the brown rice depended on the particular treatment (Table 1). We produced bright red ('Spinel Red', Smithe, 1975) rice by mixing water-soluble commercial red food dye with the brown rice. For the volatile stimulus, 100 mg of 2-methoxy-3-methylpyrazine was mixed in 1 l of distilled water and then 5 ml of this was applied to 100 g of brown rice just prior to the daily feeding trial. We prepared methiocarb-treated rice (0·025% g/g) by mixing the appropriate amount of repellent (Mesurol 75% wettable powder, Mobay Corporation, Kansas City, Missouri, USA) in 30 ml of water and adding this to 1 kg of brown rice in a rotating tumbler.

We placed 100 g of food in each bowl at the beginning of the test period and reweighed the contents 3 h later. We placed two bowls of food identical to that presented to the birds under bird-proof screening to determine change in mass due to moisture. Consumption data were adjusted accordingly.

The methiocarb-pyrazine odour (MP-O) and methiocarb–colour-pyrazine odour (MCP-O) treatment groups were exposed to the odour, but not the taste, of the volatile stimulus. Brown rice (100 g) treated with methylpyrazine was placed in a food bowl under a wire screen supported by an aluminium ring. Then, 100 g of brown rice treated with either methiocarb or methiocarb-colour was added on top of the wire screen, 4 cm above the volatile-treated rice.

We calculated suppression ratios for brown rice consumption and for total food consumption. Each bird's daily consumption was divided by the sum of that day's consumption plus the consumption on day 1. A value of 0·5 indicated indifference to the treatment, while lower ratios reflected increased avoidance. We analysed the ratios in a 2-way (treatment, days) repeated measures ANOVA. Tukey HSD tests (Steel and Torrie, 1980) applied *post hoc* identified significant differences among means ($P<0·05$).

3. Results

3.1. Suppression of brown rice consumption

Brown rice consumption was affected by treatments ($F=12·0$; d.f. = 6,21; $P<0·001$), day ($F=90·2$; d.f. = 2,42; $P<0·001$), and the interaction of these variables ($F=6·2$; d.f. = 12,42; $P<0·001$). Each treatment group produced a suppression ratio lower ($P<0·05$) than that of the control group. Across treatments, daily rice suppression ratios differed ($P<0·05$) from one another, being lowest on day 2 and highest on day 4.

On day 2, suppression ratios of the treatment groups with methiocarb were lower ($P<0·05$) than the control, but they did not differ ($P>0·05$) from each other (Table 2). On day 3, when no methiocarb was on the rice, suppression of rice consumption was greatest in the methiocarb-colour and methiocarb-color-pyrazine taste groups. The methiocarb-pyrazine odour group no longer displayed a suppression ratio different from the control group. On day 4, with all treatments absent, consumption did not differ ($P>0·05$) among groups.

Table 1. Experimental treatments presented to Red-winged Blackbirds in 4-day feeding trials. Methiocarb was applied at 0·025% (g/g), colour was water-soluble red dye, and methylpyrazine was applied at the rate of 0·5 mg per 100 g brown rice

Treatment gorup	Condition of brown rice			
	Day 1	Day 2	Day 3	Day 4
Control	Plain	Plain	Plain	Plain
M	Plain	Methiocarb	Plain	Plain
MC	Plain	Methiocarb + colour	Colour	Plain
MP-O	Plain	Methiocarb + pyrazine odour	Pyrazine odour	Plain
MP-T	Plain	Methiocarb + pyrazine taste	Pyrazine taste	Plain
MCP-O	Plain	Methiocarb + colour + pyrazine odour	Colour + pyrazine odour	Plain
MCP-T	Plain	Methiocarb + colour + pyrazine taste	Colour + pyrazine taste	Plain

Table 2. Suppression ratios of rice consumption by Red-winged Blackbird groups (n = 4 per treatment) during feeding trials with colour, taste, and olfactory stimuli. On day 2 rice was treated with 0·025% (g/g) methiocarb plus the sensory cue; on day 3, rice was treated with the cues only; on day 4, all rice was untreated. Means sharing the same letter are not significantly different (P > 0·05, Tukey HSD test)

	Day of trial					
	2		3		4	
Treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
MCP-T	0·01 A	0·00	0·01 A	0·00	0·51 A	0·03
MP-T	0·08 A	0·03	0·27 B	0·15	0·58 A	0·03
MCP-O	0·09 A	0·07	0·17 AB	0·10	0·54 A	0·02
MC	0·10 A	0·02	0·02 A	0·00	0·48 A	0·04
MP-O	0·14 A	0·01	0·37 BC	0·09	0·46 A	0·04
M	0·23 A	0·02	0·34 B	0·07	0·43 A	0·07
Control	0·55 B	0·02	0·58 C	0·00	0·54 A	0·01

[a] Treatment groups as in Table 1.

3.2. *Suppression of total food consumption*

There were significant differences among treatments ($F=5{\cdot}8$; d.f.$=6{,}21$; $P=0{\cdot}001$) and days ($F=9{\cdot}3$; d.f.$=2{,}42$; $P<0{\cdot}001$). Examination of the treatment effect revealed that the methiocarb-only group differed significantly ($P<0{\cdot}05$) from the control, methiocarb-colour, and methiocarb-pyrazine taste groups. Examination of the effect of days showed that total food consumption was suppressed ($P<0{\cdot}05$) on day 2 relative to days 3 and 4.

4. Discussion

The effect of colour on the suppression of rice consumption (Table 2) was consistent with previous findings (Avery and Nelms, 1990). The three treatments combining colour with methiocarb were the only ones to suppress rice consumption below 0·2 (equivalent to 75% reduction) on the third test day. In fact, suppression by methiocarb plus colour was equivalent to that in an earlier study (Avery and Nelms, 1990) when methiocarb was applied at five times the rate used in this study. On the other hand, when colour was not part of the treatment, rice consumption was not suppressed as neither pyrazine odour nor taste acted as a conditioned stimulus.

At the rate used in this study, methylpyrazine is not repellent to Red-winged Blackbirds (Avery and Nelms, 1990). The usefulness of this compound as a conditioned stimulus appears to depend on the strength of the unconditioned stimulus (Nachman and Ashe, 1973; Andrews and Braveman, 1975). Paired with methiocarb at 0·125% (g/g), methylpyrazine was an effective conditioned stimuls (Avery and Nelms, 1990). Paired with methiocarb at 0.025% (g/g), it was not (Table 2). Conversely, the colour cue was an effective conditioned stimulus at each methiocarb level (Figure 1), reinforcing the notion that visual cues are predominant in the feeding behaviour of diurnal passerines (Gillette *et al.*, 1983; Avery and Nelms, 1990).

Protection of seeded crops should be particularly amenable to the use of postingestinal chemical repellents enhanced by visual and non-visual cues. Applying a bright colour will not affect a seeded crop's marketability as might occur if the colour was applied to a ripening crop. There is evidence that colour can be used effectively to deter bird predation on seeds (Akande and Obajimi, 1990). Furthermore, seeded crops are also ideal for applying partial treatment methods (Avery, 1989). Combining bright colour, an unpleasant taste, and a lower repellent rate with partial treatment in a seeded crop should substantially reduce the amount of chemical needed.

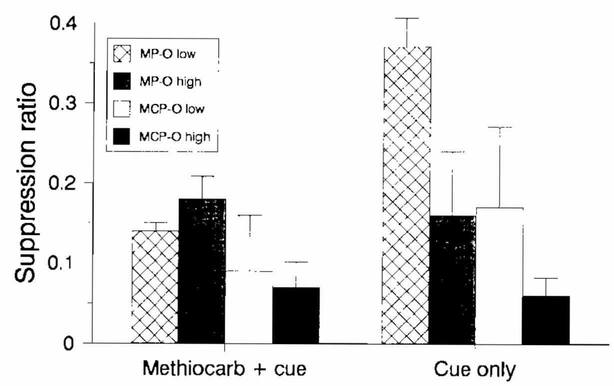

Figure 1. Rice consumption suppression ratios of groups of four Red-winged Blackbirds exposed first to rice treated with methiocarb at a low (0·025%, this study) or high (0·125%, Avery and Nelms, 1990) rate, accompanied by methylpyrazine odour with (MCP) or without (MP) a colour cue, and then exposed to rice treated with the odour-colour cue only.

Cue-enhanced repellents also may help to deter accidental ingestion by birds of highly toxic granular pesticides (Flickinger *et al.*, 1980). It might be feasible to treat such granules with bright aposematic colours in combination with a strong volatile contact repellent so that birds encounter multisensory signals that discourage foraging (Mason *et al.*, 1991, 1993).

Acknowledgements

The constructive comments of R. B. Carlson, J. R. Mason, and M. E. Tobin are appreciated. L. A. Whitehead assisted with the preparation of the manuscript.

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